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Alexander, N. E.

Ordnance and Armament (22)
Testing (14)
Strain gages - Calibration (90710);
Rocket - Firing (82550)

18300

O.S.R.D.-5846

Standard automatic calibrator for A-C bridge and amplifiers

O.S.R.D., N.D.R.C., Div. 3, Washington, D. C.

U.S. Eng. Confd'l Nov'45 19 10 photos, table, diagrs

Automatic calibrators described provide means of correlating resistance-change calibration of a strain gage and the deflection obtained on a pressure-time or thrust-time film record of rocket firing. Calibrators consist essentially of a series of relays which, by their action, display at terminals of unit a sequence of accurately known resistances which produce deflection steps on film record. By measuring trace width and knowing resistance producing step, ratio between trace width per unit resistance change is a simple calculation.

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OSRD 5846
November 1945

STANDARD AUTOMATIC CALIBRATOR

FOR A-C BRIDGE AND AMPLIFIERS

Final Report Series J Number 1.4

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Preface

The rapid expansion of static firing facilities at the Allegany Ballistics Laboratory early in 1944 created a more pressing need than ever for suitable equipment to apply calibrations automatically on every record taken with the strain-gage equipment of rocket test firing. Some preliminary work had been done on devices of this type at the Jet Propulsion Research Laboratory, Indian Head, Maryland, operated under the joint auspices of the Bureau of Ordnance, United States Navy, and the National Defense Research Committee. A two-channel calibrating unit designed by C. N. Hickman and built by the Bell Telephone Laboratories had been tried and was found very satisfactory. This work is pertinent to the project designated by the Navy Department as NO-33 and by the War Department as OD-14.

The work of constructing the calibrators was performed by the Bell Telephone Laboratories under Contract OEMsr-256 with the Western Electric Company. The testing and installation of the calibrators is listed in the Allegany Ballistics Laboratory files as Project J-10.6. This latter work was done by the Allegany Ballistics Laboratory, Pinto, West Virginia. Expenses incident to testing and installation were borne under Contract OEMsr-273 with The George Washington University.

November 1945

Acknowledgments

Full acknowledgment is made to C. N. Hickman for the general design of the calibrator units, and for the detailed design eliminating the effects of contact resistance and capacitance change. Through the efforts of H. O. Siegmund, the calibrators were built by the Bell Telephone Laboratories.

The editorial staff of the Allegany Ballistics Laboratory, under the direction of William A. D. Millson, edited this report, and the staff of the Technical Reports Section, Office of the Chairman, National Defense Research Committee, did the final editing and prepared the report for publication.

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STANDARD AUTOMATIC CALIBRATOR
FOR A-C BRIDGE AND AMPLIFIERS

Abstract

The automatic calibrators for the a-c bridge strain-gage recording equipment consist essentially of a series of relays which, by their action, display at the terminals of the unit a sequence of accurately known resistances. When connected in series with a wire strain gage and to the recording equipment, this sequence of resistances produces deflection steps on the film record. By measuring the width of the trace at each step and knowing the value of resistance producing that step, the ratio of width of trace per unit resistance change is a simple calculation. When the strain-gage factor for pressure [(lb/in^2)/ohm] or for thrust (lb/ohm) is known, the calibration in terms of pounds per square inch per unit width of trace (or pounds force per unit width of trace) appearing on a film record of rocket firing may be readily determined. The automatic calibrators, therefore, provide the means of correlating the resistance-change calibration of a strain gage and the deflection obtained on a pressure-time or thrust-time film record of rocket firing.

1. Introduction

In setting up static firing-range facilities important to the research and development of military rockets,[1/] it was desirable to have on each record of firing an over-all calibration of the a-c bridges, oscilloscope amplifier, and camera.[2/] With a calibration on each film (see Fig. 5) showing the relationship between resistance change in the gage circuit and the resulting width of trace on the film record, the pressure acting on a wire strain gage calibrated in terms of resistance change with applied pressure becomes a simple calculation.[3/]

1/ See Static range operational and fire-control equipment, by C. M. Lathrop and N. Alexander, Final ABL Report J-1 (OSRD-5855).

2/ These instruments are described in A-c bridge and pre-amplifier for strain-gage measurement of pressure and thrust, by N. Alexander, Final ABL Report J-1.3 (OSRD-5857), and The two-channel ballistics camera, by N. Alexander, Final ABL Report J-1.5 (OSRD-5858).

3/ For further details of gage calibration, reference is made to Calibration equipment for pressure and thrust wire strain gages, by C. M. Lathrop and N. Alexander, Final ABL Report J-1.8 (OSRD-5862).

A memorandum dated November 17, 1943, by C. N. Hickman on the subject "Amplifier calibrators"[4] led to construction by the Bell Telephone Laboratories of the first automatic calibrator unit. This unit was designed to calibrate two channels of a-c bridge recording equipment and is illustrated in Fig. 1. This unit was tried on the a-c bridge equipment at Indian Head, Maryland, and was later moved to Range C at the Allegany Ballistics Laboratory, Pinto, West Virginia. The performance of this unit was quite satisfactory and the results of these tests were of particular interest to the Research Division of the Rocket Branch at Aberdeen, Maryland. On request from Aberdeen, a calibrator unit incorporating some modifications was supplied by the Bell Telephone Laboratories. After trial, the unit was found satisfactory and six more were immediately ordered. When additional static firing ranges at the Allegany Ballistics Laboratory were equipped with a-c bridge recording equipment, additional calibrating units were needed. Minor changes of design were made. Of particular importance was a provision made to supply two ranges of resistance steps, and a separate unit was provided for each channel. This design has been called the standard calibrator unit (see Fig. 2). Twelve units have been supplied by the Bell Telephone Laboratories and their performance has been excellent.

2. Description of standard calibrator unit

The circuit diagram of the standard calibrator unit is shown in Fig. 3; the wiring diagram in Fig. 4. It will be noted that the device consists of five multicontact telephone-type time-delay relays and four pairs of fixed resistors. The silver switch D1 provides for the selection of one of two ranges of resistance steps that appear across terminals A and B as the calibrator goes through the cycle of operation.

The first four relays carry 4 "break" contacts and 2 "make" contacts. The "make" contacts energize the next relay. The "break" contacts remove resistors from the circuit A-B. Relay S5 has 6 "make" contacts, 4 of these place a short across A-B and 2 complete the firing circuit through the terminals marked F. The resistors used are of the noninductive precision wire-wound type, with a very low temperature

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4/ See Bibliography.

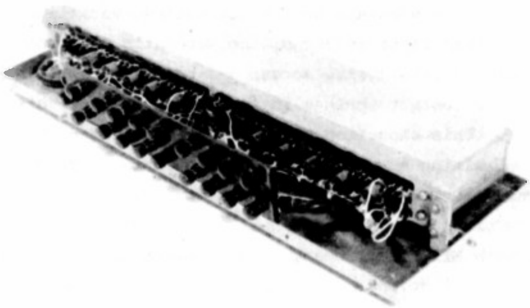
coefficient of resistance. The switch D1 is a silver knife switch having a very small contact resistance.

To minimise the effects of change in contact resistance at the relay contacts, a number of contacts are connected in parallel. Each contact spring of this type relay has double contacts. There are, actually, 4 contacts in parallel for each resistor. This feature has been found to be adequate protection against variation in contact resistance. When first received, the automatic calibrators displayed some change in capacitance across A-B because of the inclusion of additional relay contact springs in the circuit as the unit went through its cycle. This capacitance change was eliminated by installing the additional wiring shown as dashed lines on the wiring diagram, Fig. 4. This arrangement keeps all switching contacts in the circuit throughout the cycle of operation, and results in no appreciable change in bridge balance with all relays open, or all relays closed. Capacitance effects are, of course, minimised by having the calibrator connected in the ground side of the bridge.

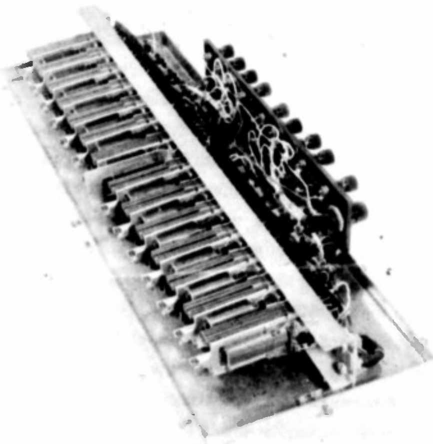
The action of the calibrator involves three circuits. In the gage circuit, terminal A is connected to the ground side of the a-c bridge equipment, and terminal B is connected to one side of the wire strain gage, the circuit being completed through the high side of the bridge directly to the gage. The control circuit, connected to the two C terminals, energizes the relays. By changing the control-circuit voltage the stepping rate of the relays may be varied. The two F terminals are connected in series with the firing circuit.

With the opening of the camera shutter on the recording equipment, relay S1 is energized through a suitable circuit, removing the short across A and B and inserting the resistors in parallel, also energizing relay S2. When relay S2 operates, the 1-ohm resistors are removed from the parallel combination and S3 is energized. When S3 acts, the 3-ohm resistors are removed from the combination and S4 acts. When this occurs, the 6-ohm resistors are removed from the circuit and S5 is energized. When S5 acts, a short is again placed across the gage circuit A-B and the firing circuit is completed. The pressure or thrust developed by the rocket motor then causes a change in resistance of the wire strain gage recording the event and a record of this change is

(A) COMPLETE UNIT



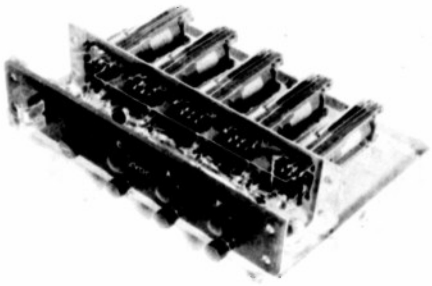
(B) UNIT WITH COVER REMOVED



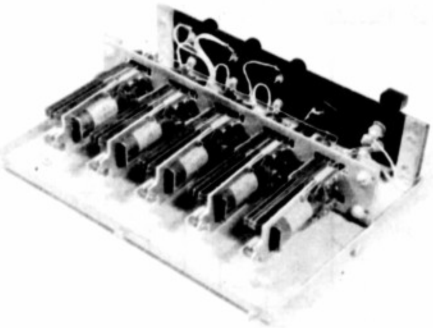
(C) RELAY OF UNIT, COVER REMOVED

FIG.1. THE FIRST AUTOMATIC CALIBRATOR UNIT (DOUBLE CALIBRATOR UNIT).

(A) COMPLETE UNIT

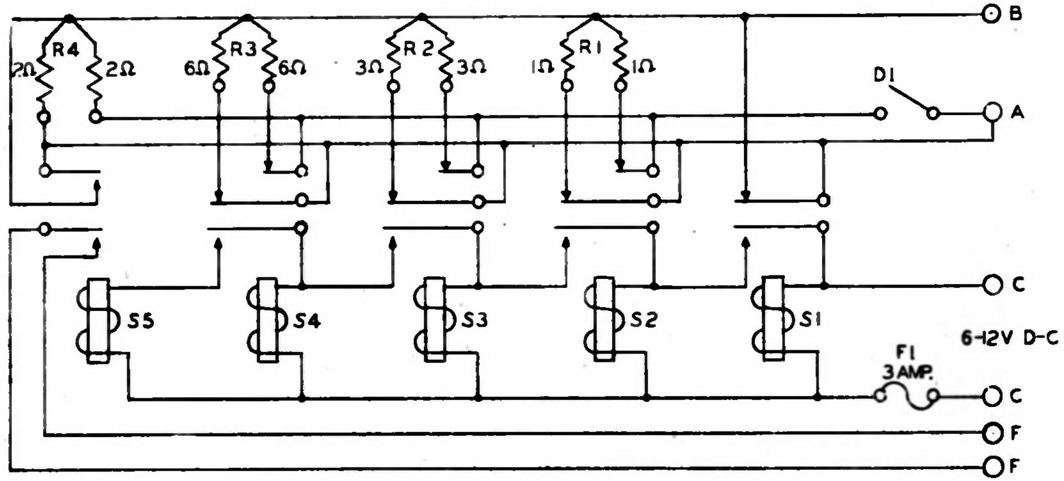


(B) FRONT VIEW OF UNIT WITH COVER REMOVED



(C) REAR VIEW OF UNIT WITH COVER REMOVED

FIG. 2. STANDARD CALIBRATOR UNIT



D1,	LEEDS AND NORTHRUP S.P.S.T. SWITCH	R1,	D-171336 RESISTANCE
		R2,	D-171338 RESISTANCE
F1.	LITTELFUSE INC. NO 1043 FUSE	R3,	D-171339 RESISTANCE
		R4,	D-171337 RESISTANCE
S1-S4,	COIL OF THE U-549 RELAY (34 OHMS) SPRING COMB. 137/137 CONTACT METAL HEAVY NO. 2, FORM NO. 283. STOP PINS 0.005 IN., OPERATE 0.063 AMP	S5,	COIL OF THE U-549 RELAY (34 OHMS) SPRING COMB. 123/123 CONTACT METAL HEAVY NO. 2 FORM NO. 283. STOP PINS 0.005 IN., OPERATE 0.048 AMP

FIG. 3. STANDARD CALIBRATOR CIRCUIT DIAGRAM

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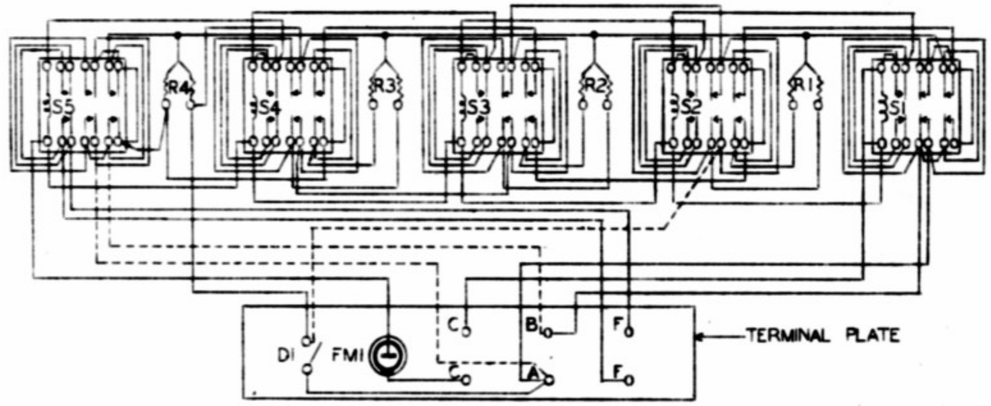

R1,	1 OHM	D1,	SILVER SWITCH	F,	FIRING CIRCUIT
R2,	3 OHMS	FM1,	FUSE HOLDER	——,	ORIGINAL WIRING
R3,	6 OHMS	C,	CONTROL CIRCUIT	- - -,	INSTALLED AT A.B.L.
R4,	2 OHMS	A-B,	GAGE CIRCUIT		
S1-S5,	RELAYS				

FIG. 4. STANDARD CALIBRATOR WIRING DIAGRAM.

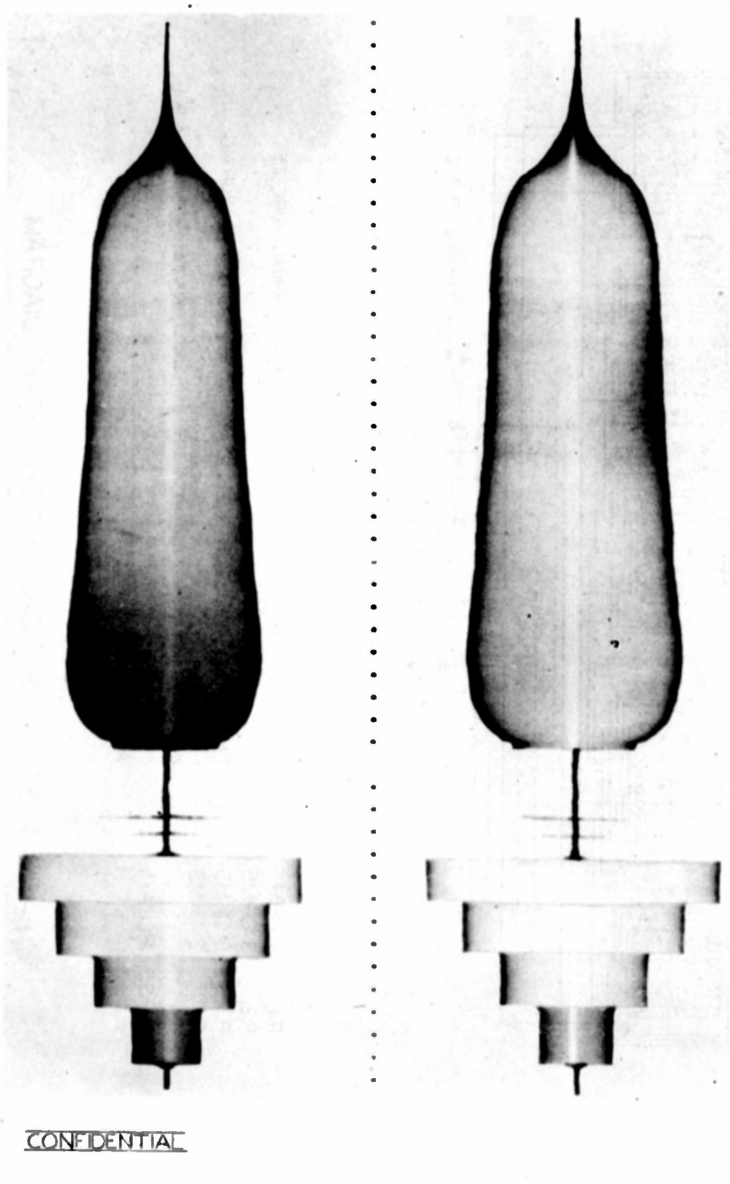

FIG. 5. SAMPLE PRESSURE-TIME RECORD SHOWING CALIBRATION STEPS

traced out on the film (see Fig. 5). When the switch D1 is open, the resistance steps appearing across terminals A and B are ½, 1, 1½, and 2 ohms. With the switch closed, the resistors are connected in parallel, reducing their total resistance by one-half, and the steps, therefore, become 1/4, 1/2, 3/4, and 1 ohm. These are the nominal values of the resistance steps. The actual values were determined by a more precise method.

The exact resistance value of each calibrator step was measured using the same bridge and galvanometer used for gage calibration.[3] The cover was removed from the calibrator and the calibrating bridge was connected in series with terminals A-B and a strain gage that had been conditioned at room temperature for several hours. A 3-volt battery (sufficient to close the relays without overheating) was connected in series with a switch to the control circuit terminals C-C. A small wooden wedge was used to block the sequence of the relays so that resistance measurement of each step could be made. The resistance was measured with all relays open, that is, terminals A and B shorted by the contacts of relay S1, which represented the resistance of the strain gage and connecting wiring. The stop wedge was then inserted in relay S2 and the control circuit energized, causing the first relay to close. The resistance was again measured, and represented the resistance of the strain gage plus the resistance of the first step. In a like manner, measurements were taken of steps two, three, and four. Then the resistance was measured with all relays closed with the contacts of S5 shorting terminals A and B. The measurement with all relays open and all relays closed provided a check on temperature changes, relay contact resistance, or other factors that might affect the zero resistance. This set of measurements constituted one observation. Five observations were made for each calibrator with the switch D1 open and with switch D1 closed.

In calculating the value of resistance for each step, the zero resistance was taken as the average of the value obtained with all relays open and all relays closed. This value was subtracted from each value obtained for the four steps. An average was then taken of the resistance of each step obtained from the five observations. This average represented very accurately the actual value of the resistance step. Table I

Table I. Standard calibrator No. 5. Resistance data for each step. All resistances in ohms.

Step No.	Observation 1		Observation 2		Observation 3		Observation 4		Observation 5		Average Resistance Change
	Measured Res.	Res. Change	Measured Res.	Res. Change	Measured Res.	Res. Change	Measured Res.	Res. Change	Measured Res.	Res. Change	
Switch D1 Open											
All relays open	600.8898		600.8856		600.8826		600.8808		600.8784		
All relays closed	600.8898		600.8856		600.8838		600.8814		600.8784		
Average zero*	600.8898		600.8856		600.8832		600.8811		600.8784		
Relay 1 closed	601.1334	0.2436	601.1310	0.2454	601.1280	0.2448	601.1256	0.2445	601.1226	0.2442	0.2445
Relays 1,2 closed	601.3824	.4926	601.3800	.4944	601.3770	.4938	601.3746	.4935	601.3716	.4932	.4935
Relays 1,2,3 closed	601.6326	.7428	601.6296	.7440	601.6278	.7446	601.6254	.7443	601.6224	.7440	.7439
Relays 1,2,3,4 closed	601.8834	.9936	601.8804	.9948	601.8780	.9948	601.8750	.9939	601.8726	.9942	.9943
Switch D1 Closed											
All relays open	600.8886		600.8850		600.8826		600.8796		600.8778		
All relays closed	600.8880		600.8850		600.8826		600.8796		600.8772		
Average zero*	600.8883		600.8850		600.8826		600.8796		600.8775		
Relay 1 closed	601.3836	0.4953	601.3806	0.4956	601.3788	0.4962	601.3764	0.4968	601.3734	0.4956	0.4960
Relays 1,2 closed	601.8846	.9963	601.8810	.9960	601.8798	.9972	601.8768	.9972	601.8738	.9963	.9966
Relays 1,2,3 closed	602.3856	1.4973	602.3826	1.4976	602.3808	1.4982	602.3778	1.4982	602.3748	1.4973	1.4977
Relays 1,2,3,4 closed	602.5878	1.9995	602.8848	1.9998	602.8824	1.9998	602.8800	2.0004	602.8770	1.9995	1.9998
Temperature °F		82.0		82.0		82.5		82.5		82.5	

*Average of the value obtained with all relays open and with all relays closed. The resistance change for each step is determined by subtracting this "average zero" resistance from the measured resistance for the step.

shows resistance data obtained for standard calibrator No. 5, which illustrates the method and precision of the device; variations are within the limit of error of the resistance-measuring equipment.

3. Conclusion

The Bell Telephone Laboratories provided 8 standard calibrator units on the first order and 4 more on a subsequent order. These units were constructed in accordance with the Bell Telephone Laboratories Drawing No. BO-105910 (the circuit diagram shown in Fig. 3) and the Bell Telephone Laboratories Drawing No. BO-105911 (the wiring diagram shown in Fig. 4). These calibrators have given excellent service with a minimum of maintenance. The only maintenance required was burnishing of the relay contacts before measuring the resistance steps or placing in service. After about six months' service, one pair of units showed some erratic action. The contacts on these units were reburnished and the resistance of the steps remeasured. The resistance of the steps had not changed appreciably in this time.

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FORG'N. TITLE:

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ABSTRACT

Automatic calibrators described provide means of correlating resistance-change calibration of a strain gage and the deflection obtained on a pressure-time or thrust-time film record of rocket firing. Calibrators consist essentially of a series of relays which, by their action, display at terminals of unit a sequence of accurately known resistances which produce deflection steps on film record. By measuring trace width and knowing resistance producing step, ratio between trace width per unit resistance change is a simple calculation.

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